

MANDREL WITH CONTROLLED RELEASE LAYER FOR  
MULTI-LAYER ELECTROFORMED INK JET ORIFICE PLATES

Technical Field

5           The present invention relates to ink jet  
printing systems, and more particularly to a mandrel  
with a controlled-release layer for use in  
fabricating multi-layer electroformed orifice plates  
used in such ink jet printing systems.

Background Art

10           In general, continuous ink jet printing  
apparatus have a printhead manifold to which ink is  
supplied under pressure so as to issue in streams  
15       from a printhead orifice plate that is in liquid  
communication with the cavity. Periodic  
perturbations are imposed on the liquid streams,  
such as vibrations by an electromechanical  
transducer, to cause the streams to break-up into  
20       uniformly sized and shaped droplets.

          Orifice plates with arrays containing  
thousands of nozzles are required for page-wide  
continuous ink jet printheads. All of the nozzles  
must be perfectly formed, all being of uniform size  
25       and free of deformities such as flat edges. The  
nozzles, which are typically about 25 micron  
diameter, require submicron smoothness. This  
requires that great care must be exercised to  
provide metallic substrates free of micron-sized  
30       defects.

          Highly polished metallic substrates can  
be made by diamond polishing. However, this is an  
expensive process that imparts high cost to the  
substrate that can be used only once. Additionally,  
35       even diamond polishing cannot ensure that every

blemish is removed. Hence, small pits can result in defective holes and rejection of entire orifice arrays.

Still other prior art for making orifice plates include permanent mandrels for plating of orifice plates. This method includes plating of thin single layer orifice plates onto metalized glass substrates. This provides the desired smooth surfaces. As the orifice plate can be peeled off from the metalized glass substrates, this method eliminates the need for corrosive etching away of the substrate, with the inherent environmental and safety hazards associated therewith. It has been found, however, that the high stresses developed during plating of the thick, multi-layer orifice plates causes the electroformed orifice plates to delaminate from the metallized substrates, making this method unsuitable for plating of thick, multi-layer orifice plates.

It is seen then that there is a need for an improved substrate that is more readily separable from electroformed orifice plate structures, to overcome the problems associated with the prior art.

#### Summary of the Invention

This need is met by the improved substrate according to the present invention, wherein a controlled adhesion makes the substrate readily separable from electroformed orifice plate structures. The present invention provides the desired smooth substrate, while minimizing the need for corrosive etching in allowing thick orifice plates to be fabricated. An organic layer is interposed between a substantial and recyclable base substrate and the electroformed orifice plate. The

organic layer provides improved smoothness and a non-damaging means for parting the orifice plate from the base substrate.

5 In accordance with one aspect of the present invention, an orifice plate structure utilizes an organic release layer interposed between a base substrate and an electroformed orifice plate.

10 Objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

#### Brief Description of the Drawings

15 Fig. 1 is a cross sectional view of a composite mandrel with an orifice plate formed thereon, in accordance with the present invention;

Figs. 2A-2G illustrate the build up of layers of Fig. 1, for fabricating orifice plates in accordance with the present invention;

20 Figs. 3A and 3B illustrate the resultant formed nozzle, when applying the technique of the present invention.

#### Detailed Description of the Preferred Embodiments

25 The present invention proposes an improved substrate having controlled adhesion, making it particularly suitable for electroforming thick and/or multi-layer orifice plates.

30 Referring to the drawings, Fig. 1 illustrates a cross sectional view of the arrangement of various layers of the structure 10, having a composite mandrel 12 with an orifice plate 14 formed therein, according to the present invention. Initially, as shown in Fig. 2A, a substrate base 16 is provided, preferably having a  
35 polished surface. The polished surface can be

achieved by any suitable means, such as mechanical polishing. As this surface will be covered by a controlled-release layer, it is not necessary to polish the surface to the degree required by the prior art. Therefore, the highly expensive diamond polishing used in the prior art can be eliminated.

The substrate used may be a metal such as brass that is not attacked by the chemicals used in electroforming processes, or glass with a chrome coating. As illustrated in Fig. 2B, a smooth controlled-release layer 18 is applied to the polished surface of the substrate 16. The smooth controlled-release layer 18 may be achieved by spin coating to apply an organic chemical layer, such as a positive photoresist, approximately 0.5 micron thick onto the substrate base. In one embodiment, the controlled-release layer 18 is chosen such that it is inherently brittle and readily dissolved in a solvent such as acetone. Commercially available resists, such as Shipley 1818, dry with a glass-like, striation-free surface.

In order to make the resist surface ready for electroplating, a conductive metal layer 20, preferably copper about 0.1 micron thick, is adherently coated, by means such as sputtering, on the surface of the photoresist layer, as shown in Fig. 2C. This thin copper layer 20 replicates the smooth surface of the resist and is ideal for deposition of thin resist dielectric pegs 22, such as is shown in Fig. 2D, which pegs define the nozzles for the orifice plate. Continuing to Fig. 2E, nickel layers 24 are adherently built up on the thin copper 20 by electroplating. Hence, the nickel layers 24 do not delaminate in process as they would if, for example, a passive metallic substrate were

used in place of the adherently coated resist of the present invention.

Two layer nickel structures are used in ink jet generators, wherein the added stiffness of the orifice plate enhances uniform transfer of vibration to the ink jets. The nickel nozzle layer 24 is composed of fine grained nickel so that the edge of the orifice is very smooth. A trench mask 26 is formed over the orifices 28 for protection during a second deposition of nickel, the reinforcing nickel trench layer 30, used to increase the overall thickness. Subsequent removal of the trench mask 26 leaves an open trench where ink can freely flow to the orifices 28. Between plating of the first nozzle layer 24 and the trench layer 30, considerable thermal and chemical stress is applied in order to activate a good bond between the two nickel layers. If the nozzle layer 24 is not held firmly to the substrate, it will peel during the activation and ruin the nozzles.

When both layers are plated, the photoresist layer 18 is removed to separate the orifice plate from the mandrel base. For removal and recycling, the orifice plate 14 of Fig. 1 can be soaked in acetone until the parting resist layer 18 is dissolved, resulting in the structure shown in Fig. 2H. Alternatively, the multilayer orifice plate 14 may be carefully peeled, fracturing the brittle parting resist layer 18. Resist can then be chemically stripped from the orifice plate 14 and the base substrate 16. The thin copper layer 20 which has remained on the separated orifice plate is then removed with a selective etchant, leaving the completed orifice plate structure shown in Fig. 2I. The selective etchant would remove copper but not

damage the nickel during the short immersion period required to etch away the copper. The orifice plate is then ready to be assembled into an ink jet printhead.

5                   After the orifice plate is removed from the substrate, the substrate can be cleaned, and is then ready for reprocessing by applying a new photoresist release layer and a new sputtered copper layer. This process for making mandrels with the  
10                   controlled-release layer produces the desired smooth surface for thick orifice plates fabrication without the expensive polishing operations, making it cost effective even if the mandrel 12 is only used once.

15                   The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that modifications and variations can be effected within the spirit and scope of the invention.